

SUMEX-AIM

The Stanford University Medical EXperimental Computer (SUMEX) was established in January, 1974, to provide the first shared national computing facility for medical research. Directed by Dr. Joshua Lederberg, Professor and Chairman of the Department of Genetics, SUMEX is an innovative effort to help biomedical scientists meet today's research requirements and to explore computer applications in many health fields ranging from basic research to bedside care. The project is funded by a grant from the Division of Research Resources of the National Institutes of Health (Biotechnology Resources Branch) for an initial term that expires in July, 1978.

At present, SUMEX consists of a powerful PDP-10 computer available to approved users throughout the United States over a computer communications network on a time-shared basis. The project's goals over the next 5 years are: 1) the encouragement of applications of artificial intelligence in medicine (AIM), and 2) the managerial, administrative and technical demonstration of a nationally-shared technological resource for health research.

Such a resource offers scientists both a significant economic advantage in sharing expensive equipment and a greater opportunity to share ideas about their research. This is especially true in computer science, a field whose intellectual and technological complexity has made it difficult to avert the development of relatively isolated research groups. Each group may then tend to pursue its line of investigation with limited convergence on working programs available from others. The SUMEX-AIM project seeks to lower these barriers to scientific cooperation in the field of artificial intelligence applied to health research.

ARTIFICIAL INTELLIGENCE

The term "artificial intelligence" (AI) refers to research efforts aimed at studying and mechanizing information processing tasks that generally have been considered to require human intelligence. The current emphasis in the field is to understand the underlying principles in efficient acquisition and utilization of material knowledge and representation of conceptual abstractions in reasoning, deductive and problem-solving activities. AI systems are characterized by complex computational processes that are primarily non-numeric, e.g., graph-searching and symbolic pattern analysis. They involve procedures whose execution is controlled by different types and forms of knowledge about a given task domain, such as models, fragments of "advice" and systems of constraints or heuristic rules. Unlike conventional algorithms commonly based on a well-tailored method for a given task, AI procedures typically use a multiplicity of methods in a highly conditional manner—depending on the specific data in the task and a variety of sources of relevant information. The tangible objective of this approach is the production of computer programs which, using formal and informal knowledge together with mechanized hypothesis formation and problem-solving procedures, will be more general and effective consultative tools for the clinician and medical scientist.

Each authorized project in the SUMEX-AIM community is concerned in some way with the application of these principles to medical problems. This type of "intelligent" assistance by computer program is perhaps best illustrated by the following brief descriptions of some SUMEX-AIM projects.

DENDRAL

The DENDRAL project at Stanford, under the direction of Dr. Lederberg, Professor Edward Feigenbaum, Computer Science, and Professor Carl Djerassi, Chemistry, is aimed at assisting the biochemist in interpreting molecular structures from mass spectral and other chemical information. In cases where the characteristic spectrum of a compound is not catalogued in a library, the DENDRAL programs carry out the rather laborious processes a chemist must go through to interpret the spectrum from "first principles." By symbolically generating "reasonable" candidate structures from hints within the spectrum and a knowledge of organic chemistry and mass spectrometry, the program infers the unknown structure to be the one which best explains the observed spectrum. There is no direct algorithmic path available to determine such a molecular structure from the spectral data—only the inferential process of hypothesis generation and testing within the domain of reasonable solutions defined by a knowledge of organic and physical chemistry.

This process, as implemented in the computer, is a simplified example of the cycle of inductive hypothesis—deductive verification that is often taught as a model of the scientific method (Whether this is a faithful description of contemporary science is arguable, and how it may be implemented in the human brain is unknown. Regardless, these are useful leads rather than absolute preconditions for the pragmatic improvement of mechanized intelligence for more efficient problem-solving.). The elaboration of these approaches with existing hardware and software technologies is the most promising approach to enhancing computer application to the vaguely structured problems that dominate our task domains.

THE RUTGERS PROJECT COMPUTERS IN BIOMEDICINE

Professor Saul Amarel, a Rutgers University computer scientist, directs several research efforts designed to introduce advanced methods in computer science—particularly in artificial intelligence and interactive data base systems—into specific areas of biomedical research.

For example, a group of computer scientists led by Professor Casimir Kulikowski is developing computer-based consultation systems for diseases of the eye in collaboration with Dr. Aran Safir, an ophthalmologist from the Mount Sinai School of Medicine. An important development in this area is the establishment of a national network of collaborators for computer diagnosis and treatment of glaucoma. The computer system, which includes an elaborate pathophysiologic model of the disease, is being tested through the SUMEX-AIM network at three eye centers: Mount Sinai Hospital and Medical Center, New York; Washington University, St. Louis; and The Johns Hopkins University, Baltimore. Glaucoma, in one form or another, affects 2% of all people over 40 years of age. It is a disease in which increased pressure within the eye may lead to irreparable optic nerve damage and blindness. The computer-based program has great potential for assisting clinicians and researchers in understanding the disease, diagnosing it more accurately and improving its treatment.

In another project, Professor Charles Schmidt, a social psychologist, is developing a theory of how people arrive at interpretation of the social actions of others. The theory will be tested in situations such as the psychiatric interview and the legal trial. The computer system which currently represents the theory is called "Believer." It includes a large body of statements about people's motivations and actions. The SUMEX-AIM environment provides an excellent medium for collaboration between Dr. Schmidt's group and other researchers around the country in the

development and testing of this computer-based theory.

The Rutgers project includes, in addition, several fundamental studies in artificial intelligence and system design. These provide much of the support needed for the development of complex systems such as the glaucoma consultation and the "Believer" programs.

MYCIN Computer-based Consultation in Clinical Therapeutics

Dr. Stanley Cohen, Associate Professor and Head of the Division of Clinical Pharmacology at Stanford, directs this research in collaboration with Dr. Stanton Axline and with computer scientists interested in artificial intelligence and medical computing. An evolving computer program developed to assist physician nonspecialists in the selection of therapy for patients with bacterial infections, MYCIN attempts to model the decision processes of medical experts. It consists of three closely integrated components: the Consultation System asks questions, makes conclusions and gives advice; the Explanation System answers questions from the user to justify the program's advice and explain its methods; and the Rule-Acquisition System permits the user to teach the system new decision rules or to alter pre-existing rules judged to be inadequate or incorrect. Goals for further development of the system include expansion of the consultation program to deal with infections other than bacteremias and implementation and evaluation of the system in the clinical setting at Stanford University Hospital.

COMPUTING APPLIED TO PROTEIN CRYSTALLOGRAPHY

Members of the artificial intelligence project at Stanford also are collaborating with Professor Joseph Kraut and Dr. Stephan Freer, protein

crystallographers at the University of California, San Diego. They are using the SUMEX-AIM facility as the central repository for programs, data and other information of common interest. The general objective of the project is to apply problem-solving techniques, which have emerged from artificial intelligence research, to the well-known "phase problem" of x-ray crystallography in order to determine the three-dimensional structures of proteins. The work is intended to be of both practical and theoretical value to computer science (particularly artificial intelligence research) and protein crystallography.

DIALOG

The DIAGnostic LOGic project, under the direction of Dr. Harry Pople and Dr. Jack Myers at the University of Pittsburgh, is a large-scale, computerized medical diagnostic system utilizing the methods and structures of artificial intelligence. Unlike most computer diagnostic programs, which are oriented to differential diagnosis in a rather limited area, the DIALOG system deals with the general problem of diagnosis in internal medicine and currently accesses a medical data base encompassing approximately 50% of the major diseases in internal medicine.

MISL

The Medical Information Systems Laboratory at the University of Illinois at Chicago Circle has been established under the direction of Dr. Bruce McCormick, Information Engineering, in collaboration with Dr. Morton Goldberg, an ophthalmologist at the U of I medical school. The project explores inferential relationships between analytic data and the natural history of selected eye diseases both in treated and untreated forms. SUMEX-AIM will be utilized to build a data base to be used as a test bed for the development of clinical decision support algorithms.

SUMEX-AIM Management

A significant part of the SUMEX-AIM experiment is the development of a management structure to maximize the utility of the computer capability for a national community.

Users of the SUMEX facility are divided for administrative purposes into two groups: 1) those at Stanford University School of Medicine, and 2) those elsewhere in the United States. The facility resources (computing capacity and consulting support) are allocated in equal portions to the two groups. As Principal Investigator for the SUMEX grant, Dr. Lederberg reviews Stanford medical school projects with the assistance of a local advisory committee. National users may gain access to the facility resources through an advisory panel for a national program in artificial intelligence in medicine (AIM). The AIM Advisory Group consists of members-at-large of the AI and medical communities, facility users and the Principal Investigator of SUMEX as an ex-officio member. A representative of the National Institutes of Health-Biotechnology Resources Branch (NIH-BRB) serves as Executive Secretary.

The SUMEX-AIM computing resource is initially allocated to qualified users without fee. This, of course, entails a careful review of the merits and priorities of proposed applications. At the direction of the Advisory Group, expenses related to communications and transportation to allow specific users to visit the facility may be covered as well.

SUMEX-AIM is aware of the necessity of making the facility available for trial use by potential users and collaborators. A GUEST mechanism has been established for those who have an indicated requirement for brief access to certain programs. Those who have been given an appropriate telephone number and login procedure can dial up SUMEX-AIM to exercise these programs on a trial basis.

USER QUALIFICATIONS

Applications for use of the SUMEX-AIM facility are judged on the basis of:

- 1) The scientific interest and merit of the proposed research.
- 2) The relevance of the research to the artificial intelligence approach of SUMEX-AIM as opposed to other computing alternatives.
- 3) The user's prospective contributions and role in the community, e.g., developing and sharing new systems or application programs, sharing use of special hardware, etc.
- 4) The user's capability and intentions of operating in a community-effective style for mutual advantage. Besides the programming innovations that some participants may contribute, all are expected to furnish expert knowledge and advice about the existing art in their fields of interest.
- 5) The quantitative allocation of specific elements of the SUMEX-AIM resource based on a concept of mean and ceiling planned expectations.

FACILITY INFORMATION

The computer facility, consisting of a DEC Model KI-10 CPU running under the TENEX operating system, has 256K words (36-bit) of high-speed memory, 1.6M words of swapping storage, 70M words of disk storage, two 9-track 800 bpi industry-compatible tape units, a dual DEC-tape unit, a line printer, and communications-network interfaces providing user terminal access. SUMEX is available through TYMNET and as a host over the ARPANET communications network.

Program (software) support will evolve from the basic system as dictated by the research goals and needs of the user. Initially, available programs include a variety of TENEX user, utility and text editor programs. Major user languages include INTERLISP, SNOBOL, SAIL, FORTRAN-10, BLISS-10, BASIC, Macro-10, OMNIGRAPH and MLAB.

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POTENTIAL USERS

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Procedures for access to SUMEX-AIM are governed by the:

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